ADAPTIVE PRODUCT TECHNOLOGY FOR COALBED NATURAL GAS (CBM)

William A. Grubb
Weatherford International Ltd.

ABSTRACT
The coalbed natural gas industry continues to gain both momentum and global popularity, however coalbed methane (CBM) operations pose many economic challenges to today's operators. Varying coal seam thicknesses and depths, rapidly declining water production rates, uncharacteristic well completions, sand, coal fines, etc., make it difficult to consider using just one form of artificial lift. Successful CBM production operations demand flexibility in production techniques and Weatherford has determined that a successful solution is one that offers multiple product lines in addition to modifications to conventional artificial lift products. This presentation outlines the challenges CBM production presents to operators and discusses both conventional artificial lift production techniques and new approaches. Because there is a never-ending focus on lowering lease operational expenses (LOE), operators continue to push manufacturers into modifying and/or developing new production products. This paper endeavors to provide some alternative thinking to this emerging and ever demanding industry.

INTRODUCTION
The existence of methane gas in association with coal beds has been common knowledge for over a century, but until relatively recently it has been thought of only as a nuisance or a hazard. Methane gas has contributed to major safety problems in the coal mining industry and its emission into the atmosphere has contributed significantly to the "greenhouse gases" that are recognized today as such an environmental problem. As the world considers its options for energy mix into this century and as environmental policies curtail venting, understanding of the occurrence and distribution of energy gases such as CBM will become increasingly important. CBM is formed in a similar fashion to oil and gas deposits by a process of compaction of plant and other materials over millions of years, but there the similarity ends. While oil and gas are contained in pores in the reservoir rock often under extreme pressures, CBM is held in place in coal by a process of adsorption into cleats or fractures in the coal bed and held there by water and overburden pressure. With increased depth, and therefore water pressure, these cleats close up and the space available for gas adsorption decreases accordingly, thus with few exceptions the deeper the coal bed the less attractive the production potential. In order to produce CBM the water must first be produced to reduce the pressure and allow the gas to escape from the cleats by a process of desorption, unlike conventional gas wells where the gas can be selectively produced and the water production limited to some extent. Herein lies the major economic deterrent to CBM production: the need to substantially invest in LOEs before any revenue stream can be generated from the gas production.
Current estimates of the reserves of CBM in the contiguous United States are some 700 trillion cubic feet in place with a recoverable level of some 141 trillion – it should be noted that the recoverable amount has increased to this level from estimates of 90 trillion ten years ago, as a greater understanding of the production methods needed has been accumulated. This is a huge addition to the energy reserves of this country being equivalent to approximately 5 years supply at current rates of gas utilization. CBM production today accounts for some 7.5% of total natural gas production in the United States, while vast untapped coal beds exist in Canada and worldwide that can be major contributors to energy requirements in the future.

PRODUCTION CONSIDERATIONS
The CBM industry is still in its infancy and few case studies exist of the development of most plays and as a result there are very few models available which can be used as guidelines for producing of CBM resources. Exploration costs are relatively low because the nation's coal resources are well documented and CBM exists in the majority of coals. Being relatively shallow compared to conventional oil and gas deposits, the producing wells are easy to drill and inexpensive to complete, however the producing mechanisms are more complex. The following aspects must be considered:

- CBM is trapped in the cleats or fractures in the coal bed and cannot be produced until the pressure due to the head of water is reduced. This means that a considerable time is spent, pre-gas production, in removing the water so that the gas in place can be produced.
- Water production rates at the beginning of the well life can be very high and the associated costs of producing and disposing of the water can result in high initial LOE.

- The disposal of the produced water itself presents a problem as it can range from potable to heavily saline. It may be possible to dispose of it on the surface if the water quality meets federal and/or state standards for reuse, however if not it may be necessary to dispose of it by injection into a compatible subsurface formation. As a result the disposal costs can vary from a few cents to upwards of a dollar per barrel, potentially adding considerably to the investment and LOE requirements.
- Once the coal bed has been dewatered and gas production established, the water production rates are relatively low and the artificial lift mechanism used has to be flexible enough to handle this fluctuation or it may need to be changed out to accommodate them.
- Water production rates once gas production is established will vary widely from well to well and from field to field. For example, in the Powder River Basin of Wyoming the average rate of water production is some 400 bbls/day/well while in the San Juan Basin of Colorado/New Mexico this average is only 25. The water/gas ratios vary from 2.75 bbls/mcf, in the former, to 0.031 bbls/mcf in the latter. Again the choice of artificial lift system (ALS) is critical to allow performance at optimum levels and to minimize LOE.
- Typically, in-fill wells will come on production at higher gas ratios as much of the water has already been pumped off. Therefore, the best lift system for an in-fill well will often differ from that used in an adjacent well.
- The quality of the water must also be taken into consideration, including its corrosive properties, the presence of sand, coal fines and even small chunks of coal can all have a devastating effect on the artificial lift mechanism used. As a result the choice of equipment in design, material, maintenance schedules etc. can all have a major effect on the viability of the operation. The well completion itself should be tailored to suit the particular situation, allow for ease of access to change the artificial lift equipment if required and permit an unrestricted flow path for the gas.

CONVENTIONAL CBM PRODUCTION APPROACHES

Traditionally, operators fashioned their operations after conventional oil and gas techniques. Everything from drilling to completions to the utilization of conventional oil and gas artificial lift equipment. This approach had a negative impact on the bottom line. Capital costs increased to a point to where some lease operations were unprofitable, especially during low gas prices. In addition standard oilfield lift equipment is manufactured for more difficult environments that also impacted the operational expenses in a negative manner.

Conversely, when operators adapted a water well approach in their drilling and completion techniques initial capital expense improved however the use of conventional water well artificial lift equipment performed poorly. Again, operational expenses increased.

During the early stages of establishing the CBM production industry many mistakes were made because the concept was perceived to be akin to established industries:

- The oil and gas production industry was of course well developed and to begin with oil and gas operators got into the CBM business using techniques, methods and operating experience which were well proven in their own industry. However, they proved to be inappropriate and as a result many of these operators were discouraged from further involvement.

- Similarly the water well industry was well established but what worked there did not suit CBM production and additional large scale operators were discouraged.

Operators must recognize that the CBM production industry is unique and requires a different methodology from other established industries. Each well, each coal bed is different and requires a unique approach. The keys to success in dewatering and producing CBM wells is to maintain a low bottom-hole pressure and <u>not</u> to shut the well in, as water can and sometimes does re-flood the coal seam. The main objectives and decision drivers for operators are:

- Mean time to failure or run life of the equipment used for artificial lift
- Capital expense (CAPEX)
- Lease Operating Expense (LOE)
- Deliverability and production rates.
- A comprehensive overall development plan for the field.

COMPLETION METHODS

The type of completion used for a CBM well will depend on the individual well characteristics, which in turn depend on the adequate collection and correlation of data. There are three main completion configurations in common use:

- Open hole or cavity completions in which the well is drilled down to the top of the coal bed, casing is set and the coal seam then drilled or under-reamed with air or under-balanced drilling techniques. The resultant cavity is enlarged or developed by repeated pressurization and blow-down. The main problem associated with this completion is that some artificial lift equipment has to be set above the coal, limiting the drawdown capability. Conversely, to overcome this completion problem, larger holes may have to be drilled to accommodate alternate equipment types.
- Vertical cased hole hydraulically fractured completions in which the initial hole is drilled and cased to bottom leaving a sump for the placement of dewatering equipment and the collection of loose coal material. The coal bed or multiple seams are then perforated and fractured to establish communication to the coal cleats. This type of completion provides the best operating conditions for lift equipment to operate efficiently and typically involves several widespread coal seams. However, initial capital cost or expenses increase with fracturing.
- Directional and/or horizontal well completions in which modern drilling techniques are used to drill several legs off the main borehole to parallel the coal seams and thereby expose a greater area of extraction and maximize cleat exposure. This type of completion, which typically incorporate a sump, is less common as coal seams tend to be very narrow and therefore difficult to parallel accurately, though advances in drilling techniques are making this approach more universally viable and cost effective. However, the added area exposed leads to far greater initial water production and require higher capacity lift equipment. This leads to faster de-watering of the coal and higher gas productivity. These types of wells come with higher capital expenses or costs, but yield optimum economics.

CURRENT ARTIFICIAL LIFT PRODUCT CAPABILITIES

As mentioned above, the choice of lift methods to be used can be critical and must take into consideration the unique characteristics of each well. There are six types of artificial lift systems that are available for consideration and the overall choice for each well may vary from a neighboring well and may require to be changed out during the life of the well. However, two of the available methods are not generally viable and are rarely considered:

- Gas lift (or air/nitrogen lift) requires a source of lift medium from the beginning which must be imported, the cost of which is generally prohibitive.
- Hydraulic pumping requires a complicated completion to allow both fluid circulation and an unrestricted flow path though which the gas can flow. However, there are still possible future opportunities for this form of lift with new technology under review.

The remaining lift systems which can be considered must go through an elimination process and detailed evaluation, including simulations, before an optimal system can be selected. The criteria that must be included in the evaluation are operating depth, well-bore deviation, well completion volume requirements and fluctuations, corrosion handling, gas handling, solids handling, coal dust handling, servicing needs, prime mover needs and overall system efficiency. The systems available for consideration are:

- **Progressing Cavity Pumps (PCP).** These have excellent solids and gas handling capabilities, high system efficiency and a wide range of production capability from one pump. However the rotor/stator fit is critical to good performance and swelling of the stator lining in the produced water can lead to seizure.
    - Additional Considerations:
        - Redesigned and simplified drivehead for lower costs
        - Redesigned and simplified surface control equipment
        - Expanded rotor/stator major and minor fits for elastomeric swelling

- **Electric Submersible Pumps (ESP).** The standard "oilfield" ESP is not generally suitable for CBM use and required some modification to make it more viable for this industry. However, ESPs specifically designed for CBM service, such as the CBM-ESP™*, incorporates special gas shrouding, unique intake screens and enhanced solids handling capabilities and is therefore particularly well suited for complex multiple leg completions.
    - Additional Considerations:
        - Compression stages to deal with abrasives, declining water rates and production gas fluctuations
        - Designed and manufactured to operate with low horsepowers, including conventional water well motors to reduce overall cost

    - All stages are ni-resist, vs. plastic to eliminate deformation or melting of stages in low or no flow applications
    - Multi-designs of enhanced gas separators to cover multiple gas production applications
    - Lower cost surface control equipment

- **Reciprocating Rod Pumps.** Whether driven by standard surface pump jacks or using less conventional hydraulic surface installations, rod pumps have excellent flexibility with alterations in stroke speed and length, plunger size and run time with the added advantage of field personnel familiarity.
  - Additional Considerations:
    - Recent advancements in manufacturing cost reductions have increased its use
    - Low profile surface units for environmentally sensitive areas

- **Plunger Lift.** This low cost form of lift is well known for its use in dewatering depleted gas wells and is excellent in handling gassy and corrosive environments. While this lift form is considered fair for handling solids and coal fines, it is severely limited in volume capability and thus more suitable for the gas production phase rather than for dewatering.
  - Modification Considerations:
    - Design characteristics must consider that lifting 100% water will require higher pressure versus lifting 100% oil or a combination of oil and water
    - Surface controlling system must be able to make adjustments by itself by using pressure readings versus using a time-based controller

In addition to determining which form of lift to use, a choice must be made as to the degree and type of automation system to be used with it to obtain the maximum levels of flexibility that are required to handle the water production fluctuations. Other major considerations which can have a major impact include the choice of metallurgy to suit the service requirements and whether the use of well screens, downhole gas separators and automated surface controllers would be advantageous.

CONCLUSION

The choices for the most efficient exploitation of CBM accumulations are wide and varied requiring a unified approach based on familiarity with the process. Early attempts by operators in this industry used the approach "make something standard fit the needs" often resulting in failures, cost overruns and economic shortfalls. The production of CBM, though related both to the oil and gas business and to the water well industry, is nevertheless unique and must be treated as such. The need for an approach by a single source which is overseen by a dedicated group of engineers and operational personnel cannot be overemphasized.

REFERENCES

1. *C.A Rice, V. Nuccio – Water Produced with Coal-Bed Methane, USGS Nov. 2000*
2. *V. Nuccio – Coal Bed Methane: Potential and Concerns, USGS Oct. 2000*
3. *U.S. Geological Survey Energy Resource Surveys Program*
4. *W.A. Grubb – "Purpose Fit" Technologies Key Part of Equation for CBM Production Economics, American Oil and Gas Reporter Jan 2003.*
5. *Weatherford develops Proprietary Pump to Recover Vast Resource – W Magazine, September 2002*

ACKNOWLEDGEMENTS

The author wished to acknowledge Weatherford International Ltd. for permission to publish this paper.